# Climate change and soil carbon sequestration potential in the North China Plain

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*Joint Global Change Research Institute*

US Department of Energy – China Meteorological Administration Science Meeting

27-29 October, 2003

Beijing, PR China

Battelle

Pacific Northwest National Laboratory

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# Objective

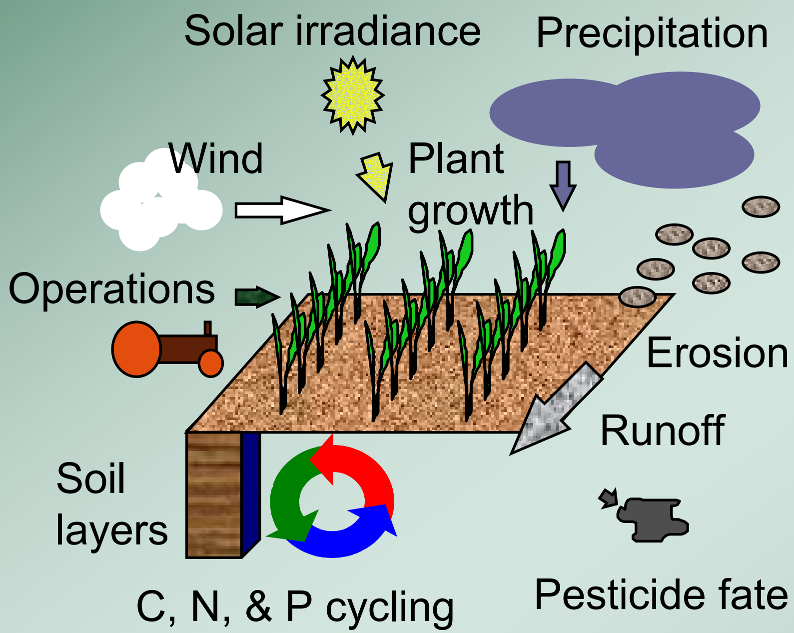
- To combine climate change assessment techniques with soil carbon sequestration science and modeling to assess the potential of agricultural soils of the Huang-Hai Plain of China to act as sinks of atmospheric $CO_2$ under changing climate

# Previous Work

- Ms. Leng Sun visited Pacific Northwest Nat'l Lab offices in Washington, DC in 2001
- Carried out climate change study in North China Plain
  - Used HadCM2 scenarios with and without sulfates
  - Developed a set of 18 representative farms to be run with EPIC model
  - Winter wheat, corn, soybean and cotton crops were modeled
  - Irrigated winter wheat responded positively to greenhouse forcing scenario without sulfates
  - Simulation results suggested
    - Yields of summer crops could be negatively affected
    - Yield losses would be less severe in the sulfate scenario

# Integrating soil-plant-atmosphere processes at landscape and regional scales through simulation modeling

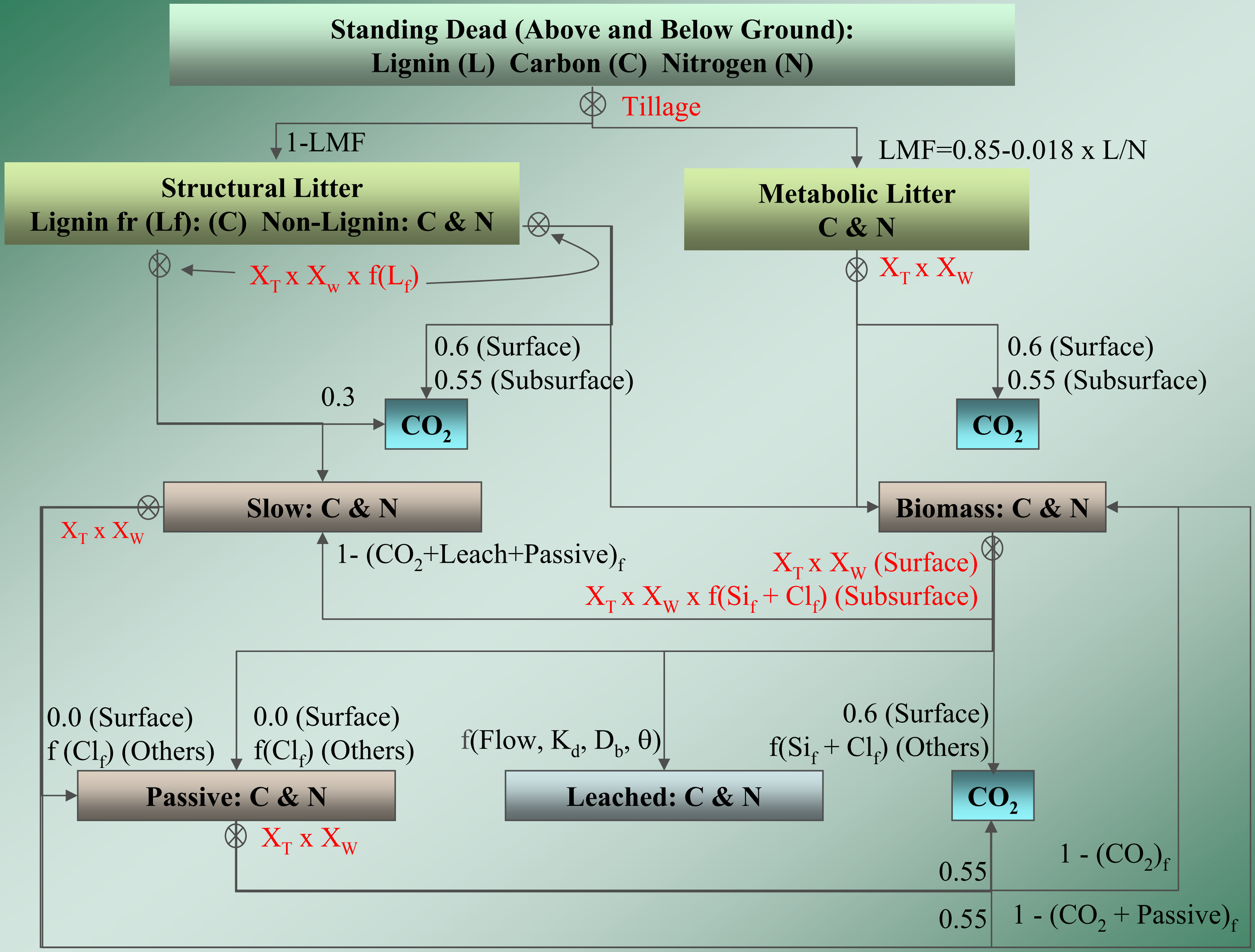
## EPIC Model




**Representative EPIC modules**

**Williams (1995)**

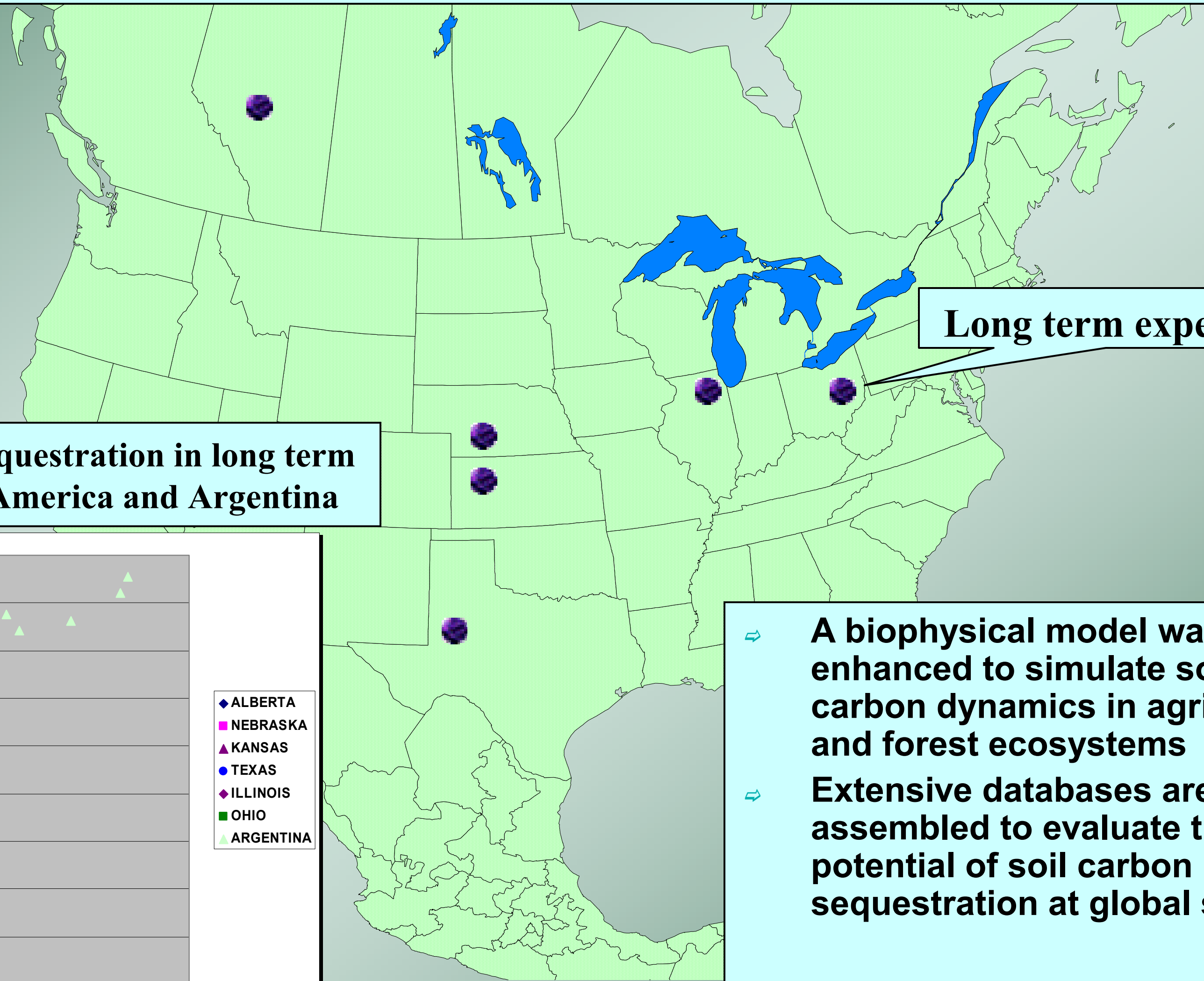
- EPIC is a comprehensive model to describe climate-soil-management interactions at point or small watershed scales
- EPIC estimates the impacts of management on wind and water erosion
- C & N modules in EPIC were recently updated (Izaurralde et al., 2001)
- Testing the model with site data is essential to improve applicability of the model for spatial and temporal extrapolation
- Combined with regional databases, EPIC can estimate processes under conditions not directly measured




**Carbon and Nitrogen flows and pools in EPIC**

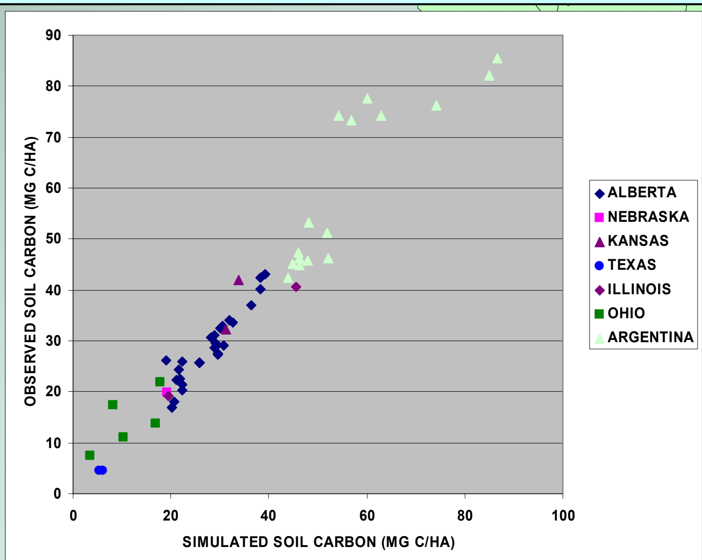
Izaurralde et al. (2001)

# Evaluating soil carbon sequestration as a technology to mitigate climate change



Long term experiments

**Modeling soil carbon sequestration in long term experiments in North America and Argentina**




- A biophysical model was enhanced to simulate soil carbon dynamics in agriculture and forest ecosystems
- Extensive databases are being assembled to evaluate the potential of soil carbon sequestration at global scales

# Development of climate change scenarios

- Obtained from IPCC 100 year monthly projections of weather for HadCM3 site developed for two SRES scenarios
  - A2 SRES scenario predicts:
    - A very heterogeneous world
    - A strengthening of regional cultural identities
    - High population growth
    - Less concern for rapid economic development
  - B2 SRES scenario predicts:
    - A world that emphasizes local solutions to economic, social, and environmental sustainability
    - An heterogeneous world with less rapid, and more diverse technological change
    - A strong emphasis on community initiative and social innovation to find local solutions

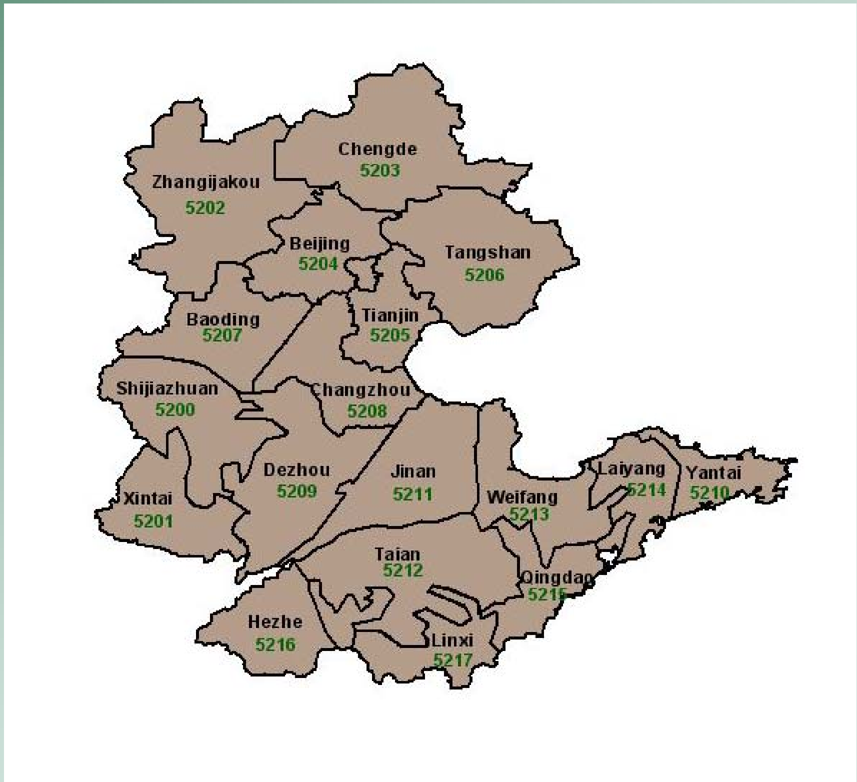
# Development of climate change scenarios (cont'd)

- Precipitation and temperature data from the scenario runs were grouped into three periods: baseline, 2030, and 2085
- Average changes in monthly averages and standard deviations of precipitation and temperature for the two future periods were calculated with respect to the simulated baseline
- Parameters (e.g., averages, standard deviations, etc.) of historical weather data in EPIC are calculated from daily records ($Std_{do}$)
- $Std_{mo} < Std_{do}$
- Changes in average values calculated from scenario data were applied directly to historical daily averages
- Changes in standard deviations for daily simulated values were calculated as follow:
  - $Std_{ds} = Std_{ms} \times Std_{do} / Std_{mo}$

# Management and simulation runs

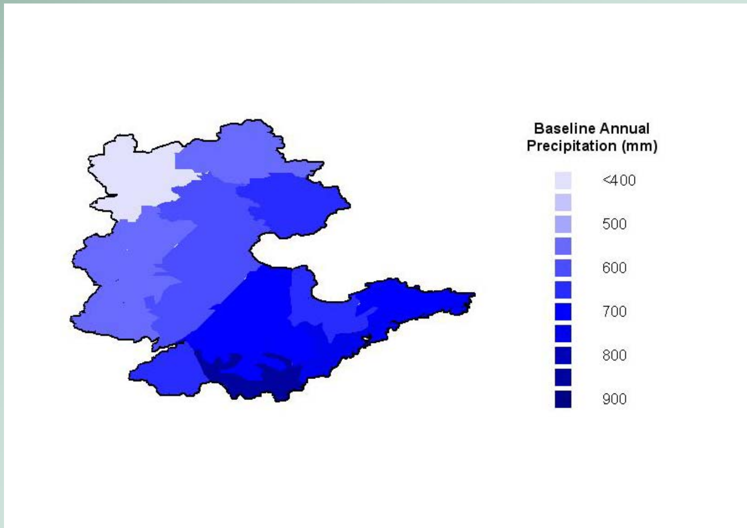
- Four management strategies
  - Traditional
  - No tillage
  - Wheat in rotation
  - Soybean in rotation
- Baseline runs obtained using traditional management
- Future period runs were obtained under 4 scenario using soil profile from previous period

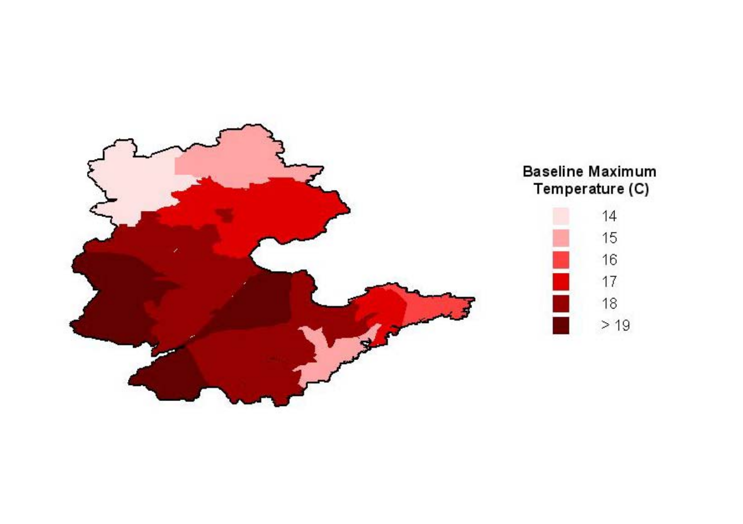
# Location and some characteristics of representative farms

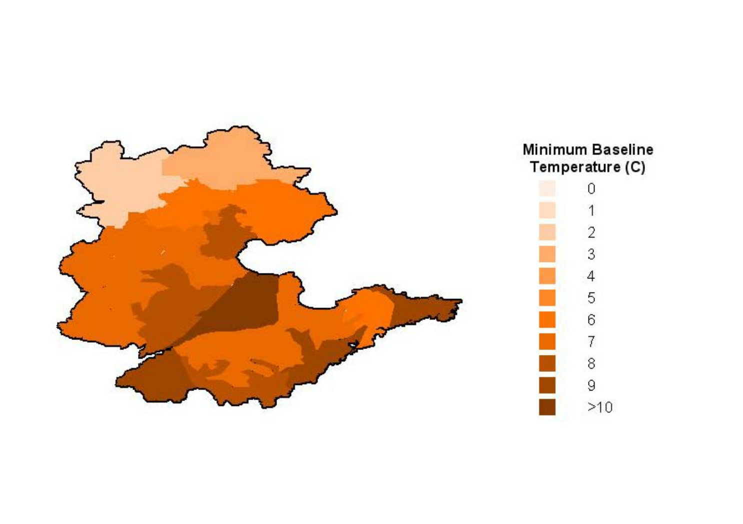



| | Db Mg/m$^3$ | SOC % | Clay % | Sand % |
|---|---|---|---|---|
| Mean | 1.35 | 1.30 | 20.3 | 53.1 |
| Max | 1.58 | 2.47 | 37.1 | 76.6 |
| Min | 1.15 | 0.30 | 9.6 | 33.5 |

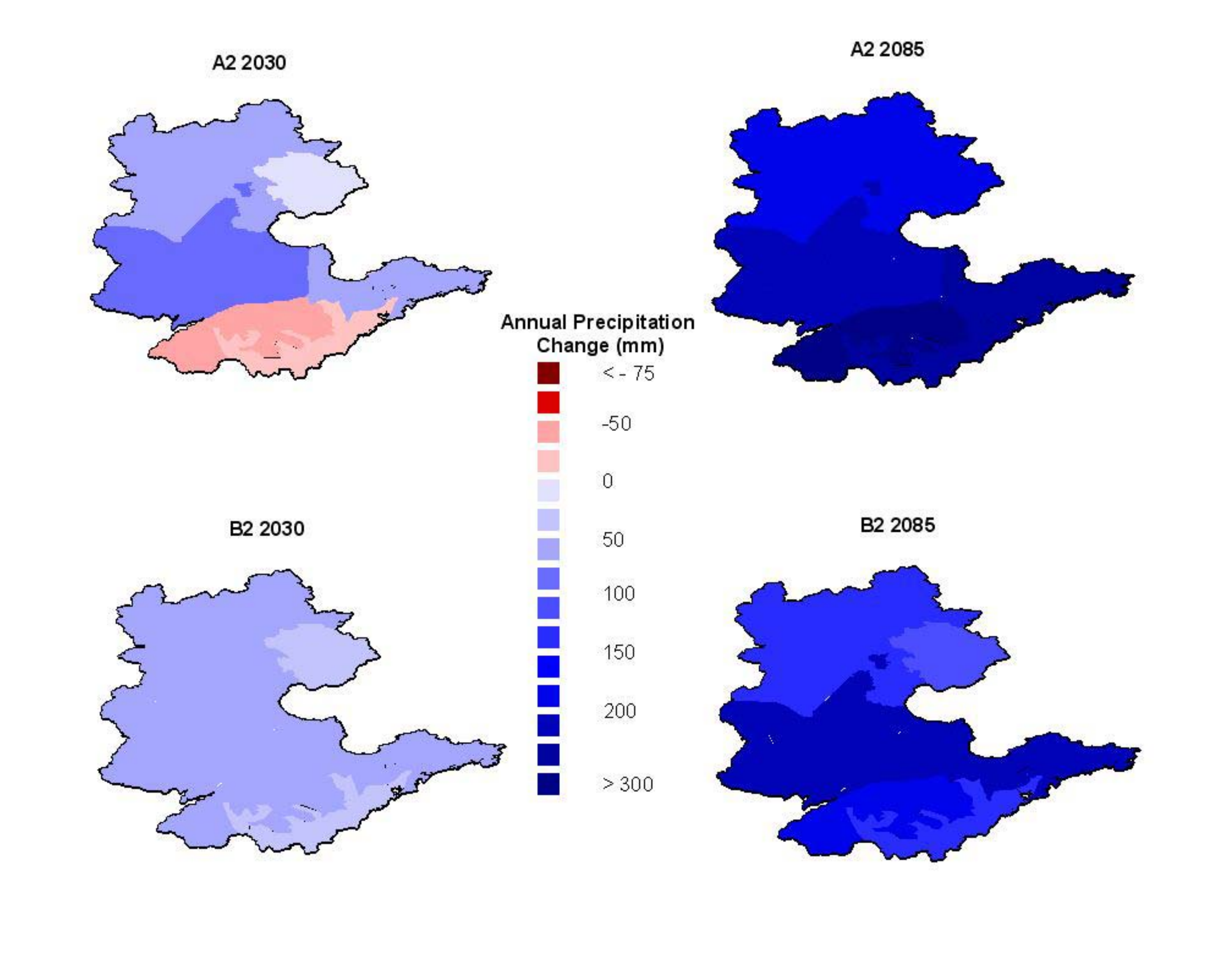
# Baseline precipitation and temperature



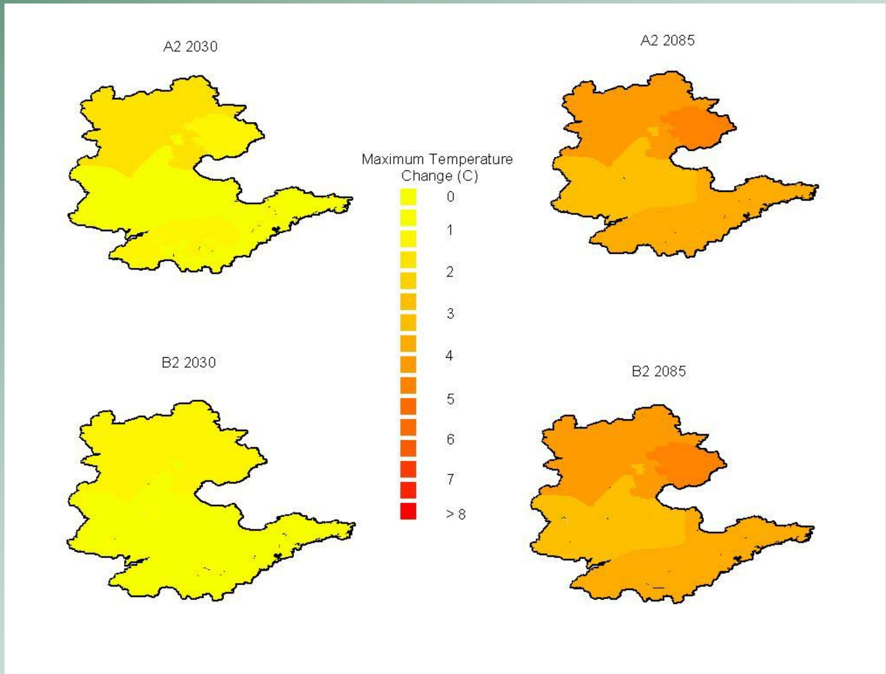



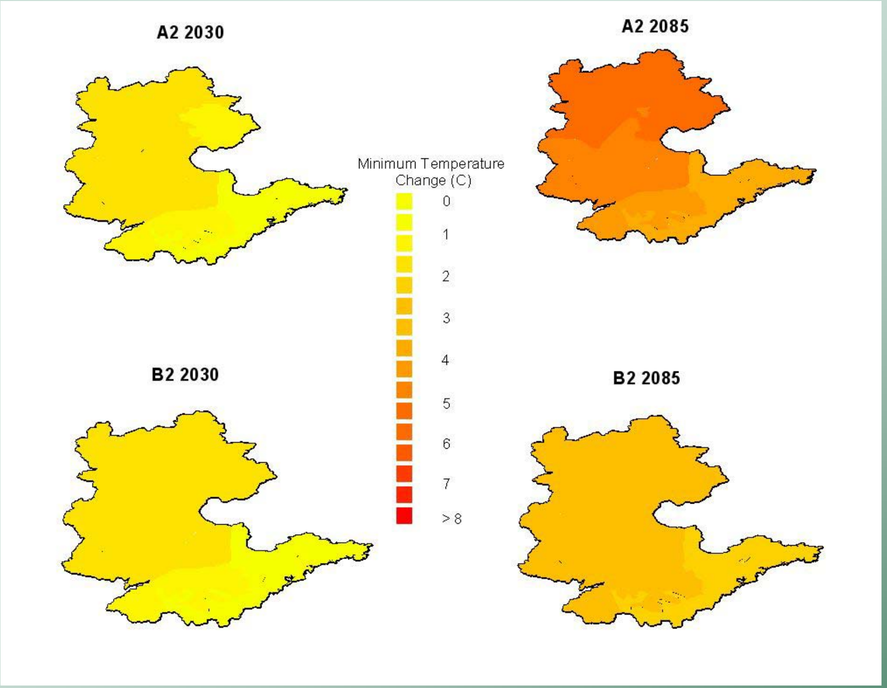



# Changes in annual precipitation for two scenarios and future periods



# Changes in air temperature for two scenarios and future periods



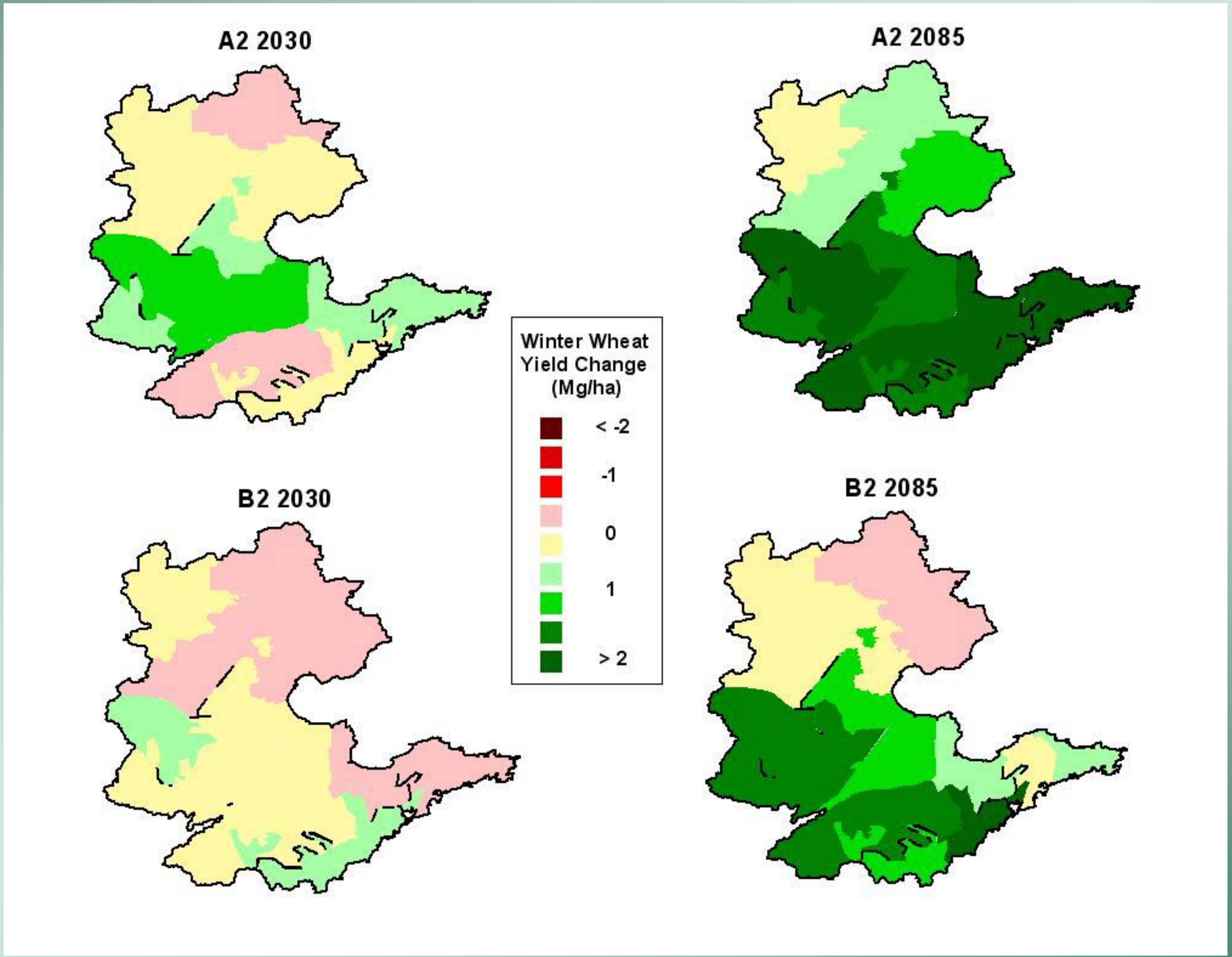
# Summary of climate changes by period and scenario

| | 2030 | | | |
|---|---|---|---|---|
| | A2 | | B2 | |
| | Temp. (C) | Prec. (mm) | Temp. (C) | Prec. (mm) |
| Avg. | 1.3 | 49 | 1.2 | 58 |
| Max. | 1.7 | 96 | 1.6 | 75 |
| Min. | 0.8 | -33 | 0.8 | 29 |
| | 2085 | | | |
| | A2 | | B2 | |
| | Temp. (C) | Prec. (mm) | Temp. (C) | Prec. (mm) |
| Avg. | 4.2 | 240 | 2.5 | 176 |
| Max. | 5.0 | 300 | 3.2 | 237 |
| Min. | 3.6 | 191 | 2.0 | 102 |

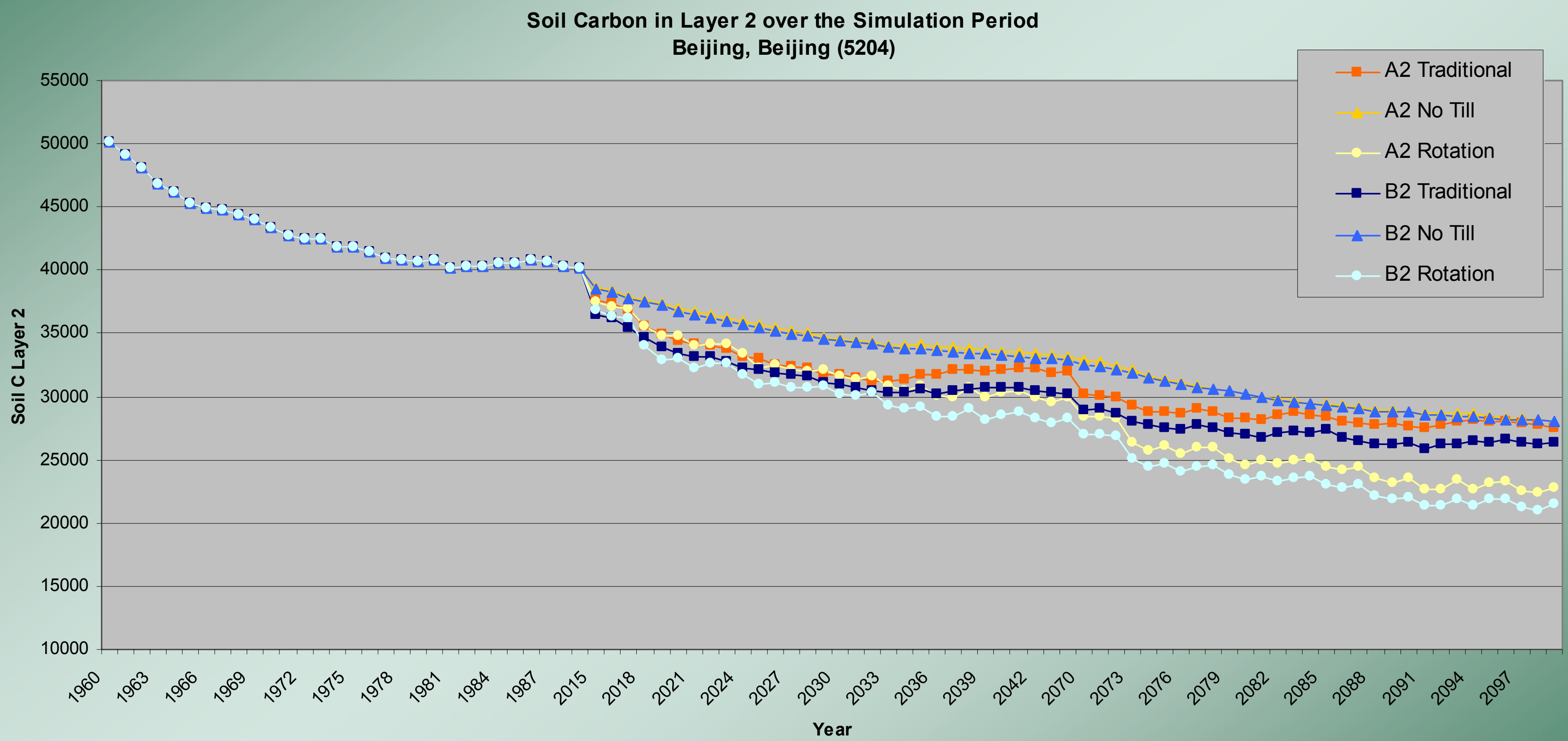
# Seasonal changes in standard deviation of average air temperature (C) under the A2 and B2 scenarios

| | A2 | B2 |
|---|---|---|
| Fall | 1.0 | 0.3 |
| Winter | 0.6 | 0.8 |
| Spring | -0.2 | -0.3 |
| Summer | 0.6 | 0.3 |

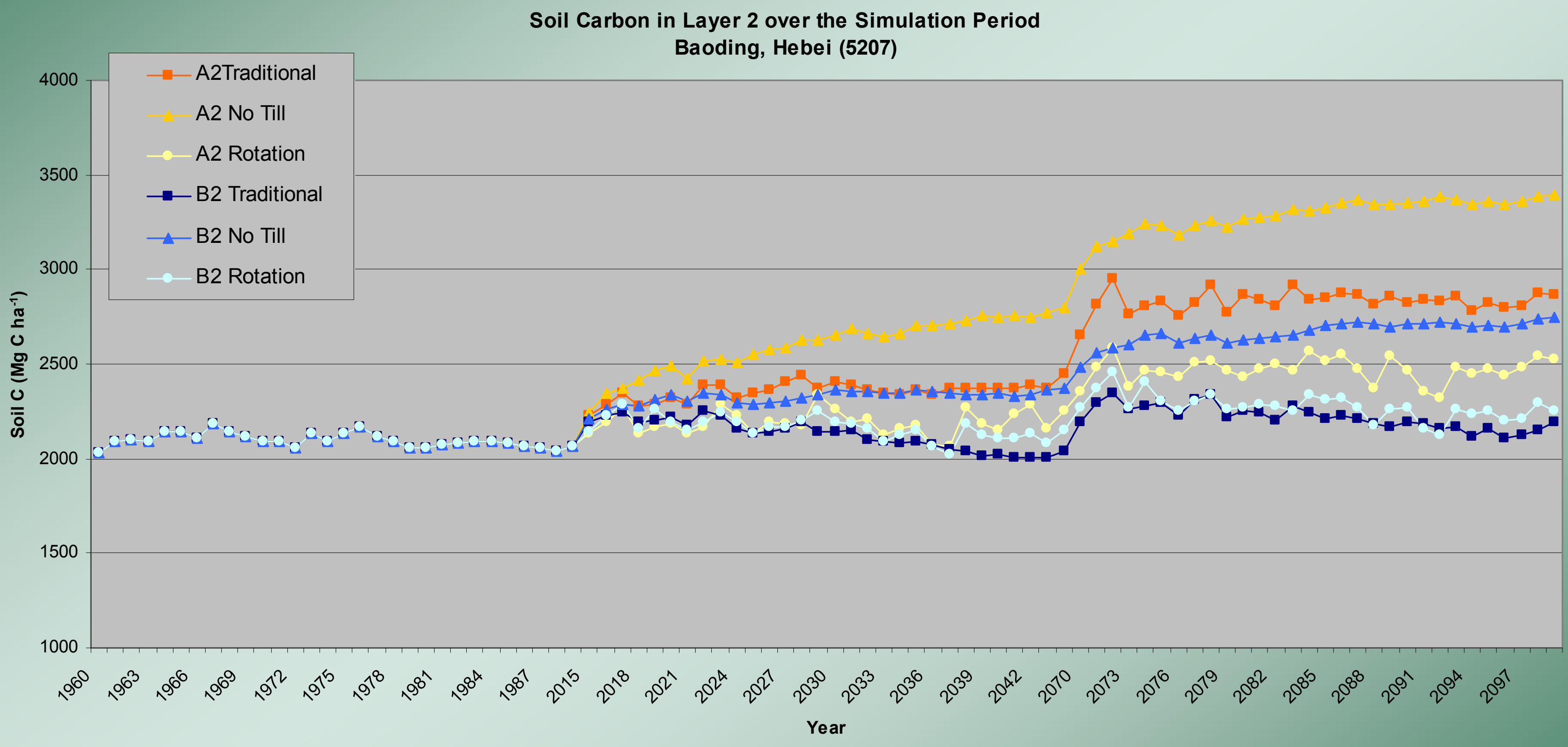
# Changes in winter wheat yield for two scenarios and future periods



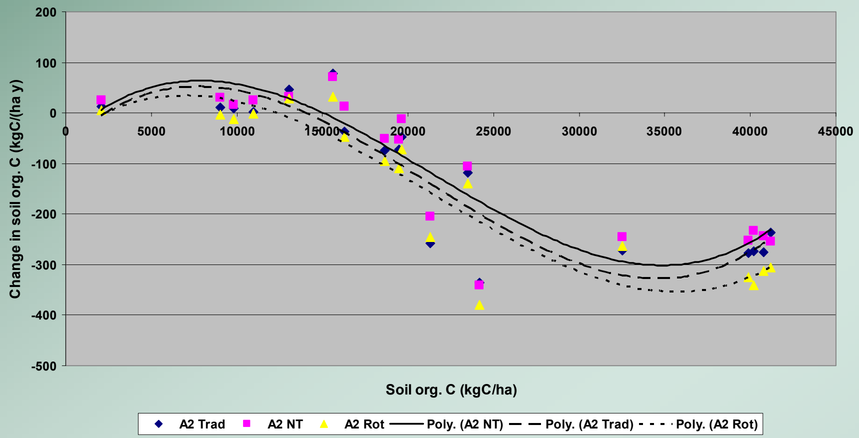
# Soil carbon dynamics for Beijing farm

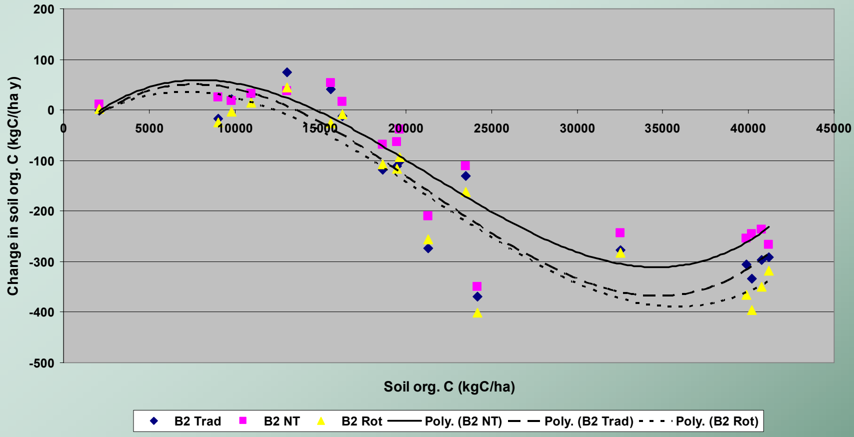


# Soil carbon dynamics for Baoding farm



# Changes in soil org. C under the two scenarios as a function of initial soil org. C content

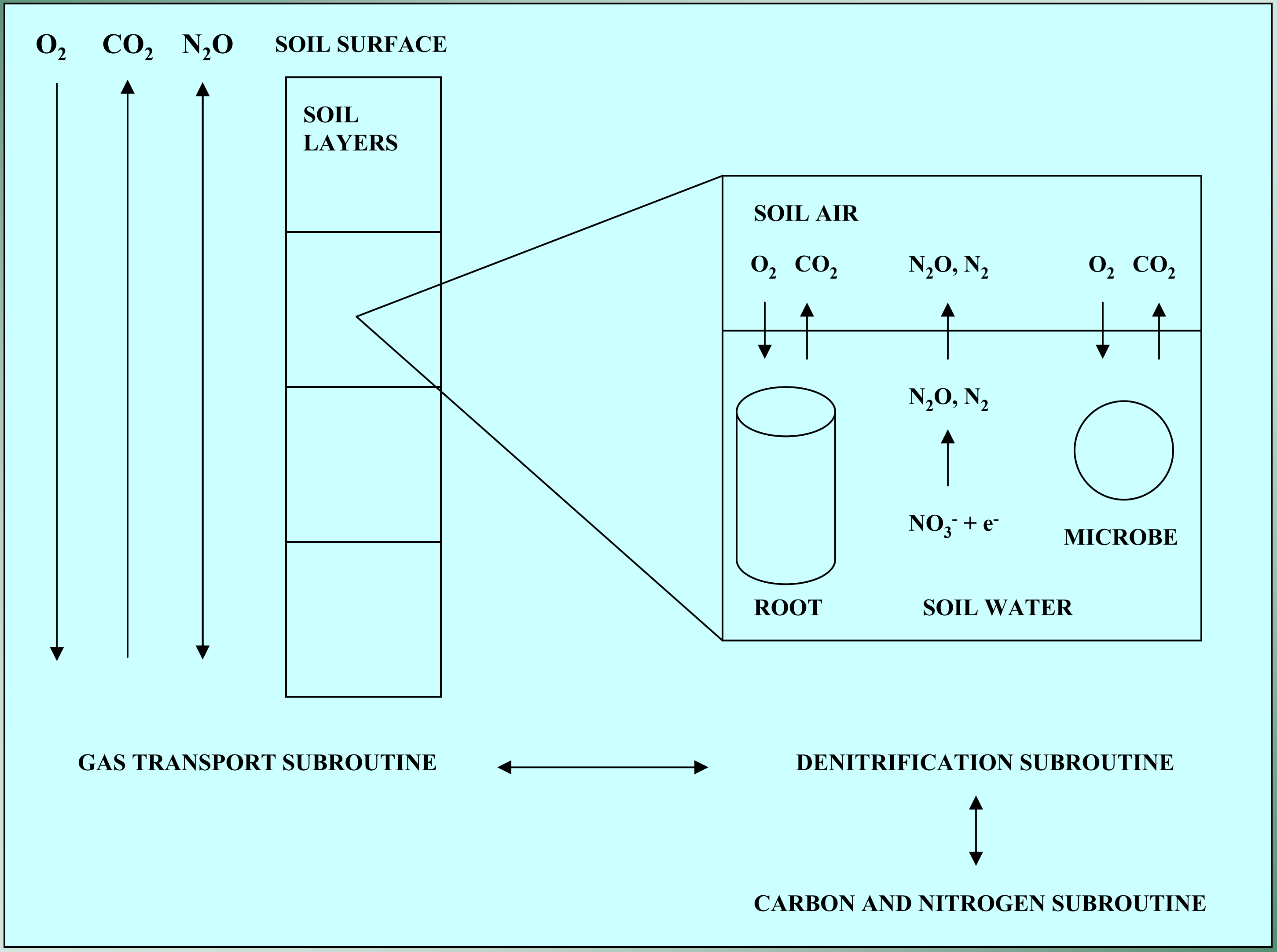


# Summary

- Climate change scenarios from HadCM3 based on SRES were successfully implemented in the weather simulator of the EPIC ecosystem model
- The scenarios incorporated for the first time changes in standard deviations of precipitation and temperature
- By 2030, changes in temperature and precipitation are rather similar between the two scenarios
- By 2085, the A2 scenario predicts warmer and wetter weather than that predicted by the B2 scenario
- Soil organic carbon stocks responded dynamically to management and climate change scenario
- Under dryland conditions, soils could lose or gain soil organic carbon
- No till practices appear to enhance gains or alleviate losses in soil organic carbon under the various climate change scenarios tested

# Current work: modeling denitrification with EPIC




Izaurralde, McGill, Williams

# Current work: landscape modeling of soil C sequestration and greenhouse gas fluxes

- APEX, the watershed version of EPIC
- C & N algorithms from EPIC incorporated in APEX
- When ready, denitrification model in EPIC will be transported to APEX

Figure 1: Schematic of process routing modeled in APEX

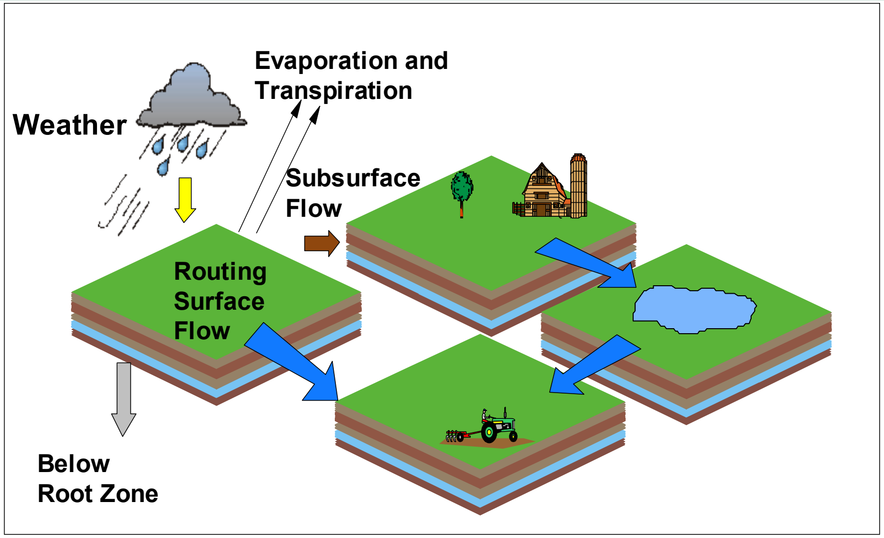



Table 3: Routing and deposition of carbon (kg $ha^{-1}$) through the modeling subarea

| | 1 | 1 → 2 | 2 | 2 → 3 | 3 | 3 → 4 | 4 | 4 → outlet |
|---|---|---|---|---|---|---|---|---|
| Originated in field | 81 | | 80 | | 82 | | 85 | |
| Deposited in field channel or floodplain | | | 57 | | 19 | | 14 | |
| Routed through the field | | | 24 | | 25 | | 27 | |
| Flow out of the field | | 52 | | 44 | | 42 | | 81 |

Thomson et al. (2003)

# Future work

- Test crop growth, water balance, and soil carbon modules in EPIC against experimental data
- Enhance databases to be able to model the North China Plain in more detail
- Expand modeling area to cover other areas of agricultural importance (cropland, grassland, land use conversions)
- Enhance collaboration with scientist form China Meteorological Administration on climate change modeling approaches, ecosystem modeling, biogeochemical cycles in managed ecosystems

# Acknowledgements


- Office of Biological and Environmental Research, Office of Science, U.S. Department of Energy
  - **http://www.er.doe.gov/production/ober/ober_top.html**
- CASMGS (Consortium for Agricultural Soils Mitigation of Greenhouse GaSes) – USDA
  - **http://www.casmgs.colostate.edu**
- CSiTE (Carbon Sequestration in Terrestrial Ecosystems) Research Consortium –DOE
  - **http://csite.esd.ornl.gov**
- Global Technology Strategy Program – PNNL
  - **http://www.pnl.gov/gtsp/**